Combustion Control Strategies For Single and Dual Element Power Burners

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Today's economic and environmental demands dictate that we get the greatest practical efficiencies from our plants. To do this we must have a basic understanding of what those efficiencies are and how we may implement them.

The use of more advanced automatic control systems for combustion control has proven to be an excellent example of systems and process automation success. The new control systems available today help improve overall combustion efficiency and burner stability over varying loads and demands. The most sophisticated systems can eliminate the need for operator input during load changes while maintaining safe and reliable fuel-air ratio control.

THE COMBUSTION PROCESS

The most common fuels used in single burner commercial and industrial boilers are natural gas and No. 2 oil. Both of these fuels consist of carbon and hydrogen. Combustion is the rapid oxidation of the fuel to release the chemical heat energy in the carbon and hydrogen. Stoichiometric, or perfect, combustion occurs when the exact proportions of fuel and oxygen are mixed to obtain complete conversion of the chemical energy in the carbon and hydrogen to yield maximum heat energy. These ideal proportions of fuel and oxygen vary directly with the Btu content of the fuel. Too much excess oxygen cools the flame and increases NO_X pollutants while too little oxygen results in incomplete combustion and sooting of the furnace or delayed combustion, which can result in a furnace explosion.

Fuel	Caloric Value	Ideal Volumetric Air / Fuel Ratio
Natural Gas	900 - 1050 Btu/CuFt.	9.71 CuFt. Air to 1 CuFt. Fuel
No. 2 Fuel Oil	138 - 140,000 Btu/Gallon	1355 CuFt. Air to 1 Gallon Fuel

Because of the specific design restrictions or lag times inherent in current burner design, a certain amount of excess air (oxygen) is always required to insure complete combustion in the furnace chamber. These restrictions take the form of delays in fuel and air flow due to friction losses in piping or lag times in the control elements. Additional influences may be in the form of site location elevation, the effects of combustion air temperature, humidity and availability, or fuel pressure and Btu content.

These design restrictions dictate some form of fuel-air metering control for safe and efficient combustion control. The systems available for this task vary in sophistication from the simplest fixed position control system to the elegant metered-cross limited fuel-air ratio control systems. This paper discusses the benefits of several of these systems as they apply to single burner packaged boilers.

COMBUSTION STRATEGIES

Fixed Position Parallel Control

Fixed position parallel control (FPC), also known as direct of jack-shaft control, is perhaps the simplest form of combustion control found on power-burner boilers. This control strategy incorporates a single positioning motor, which drives both the fuel and air positioning devices via an interconnected single mechanical linkage, the jack-shaft.

The simplicity of the FPC strategy makes it a very economical choice for small burners with modest firing rate changes. However, the fact that the fuel and air are fixed means that the fuel-air ratio is also fixed. Because of this fixed position arrangement the burner has no way to compensate for environmental changes such as combustion air temperature or fuel pressure. Additionally, the FPC strategy has no feedback to the control element to insure that the fuel and air end devices are actually functioning and in the correct position. This could lead to a crossover condition in which the fuel crosses over the air flow and results in a fuel rich furnace or other burner efficiency loses.

To help prevent a fuel rich furnace the FPC system is setup to allow additional excess oxygen to the furnace, in the range of 4.5 to 8 percent. In practice the excess oxygen is normally set at 6-7 percent to compensate for seasonal air temperature changes. This excess air results in lower ther-

Figure 1: Fixed Position Parallel Jack-Shaft combustion system with fuel-air ratio established through fixed mechanical linkages

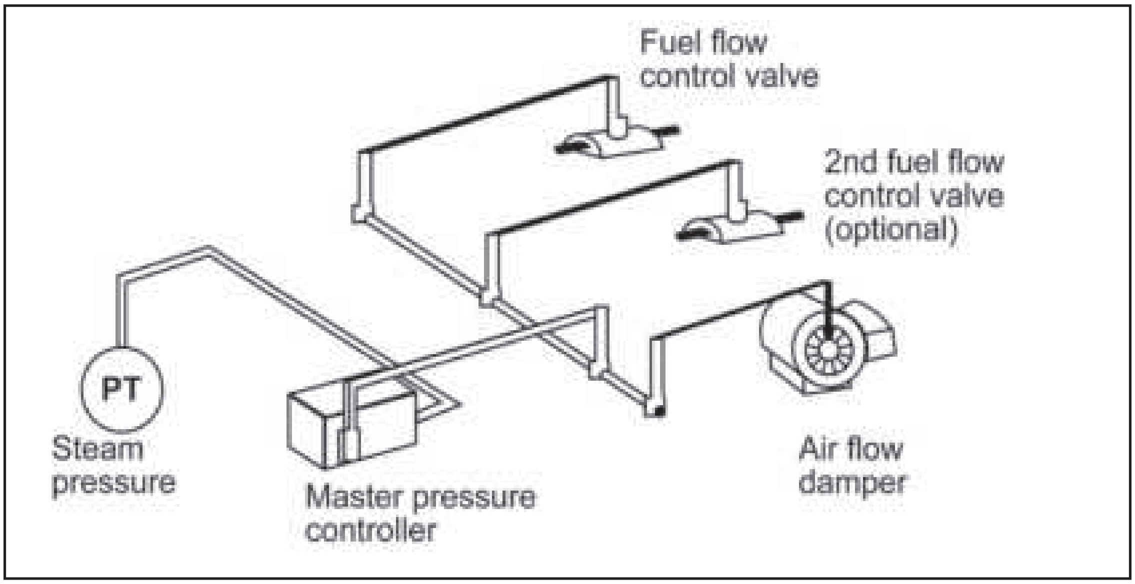
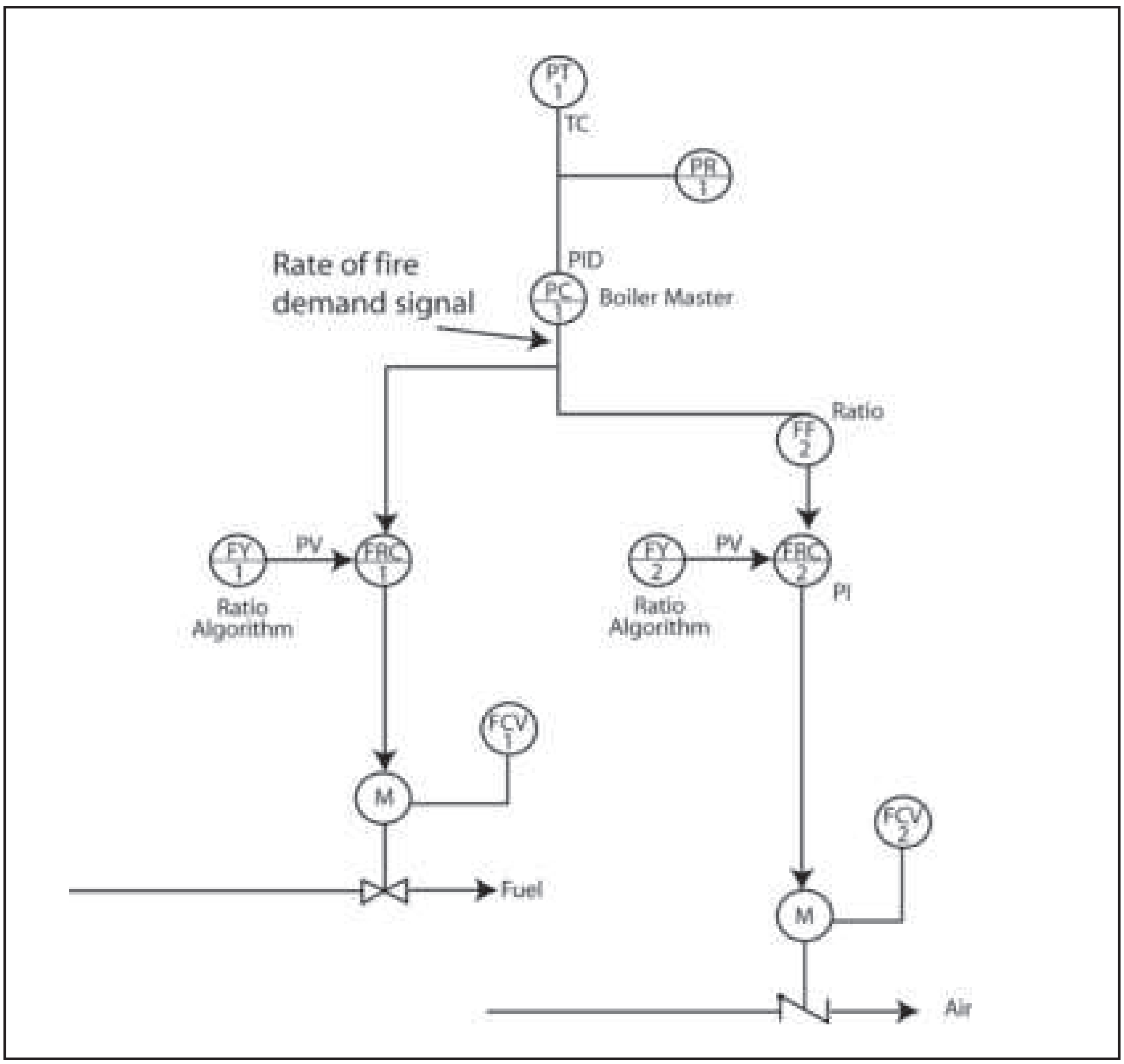


Figure 2: Parallel Position



mal efficiency by burdening the burner with unnecessary air, which only serves to cool the furnace and increase NO_X production.

Parallel Positioning Control Systems

Parallel positioning control (PPC) systems function very much like a Fixed Position Parallel system except that the fuel and air end devices are separated and driven by their individual positioners. Modern electronic PPC systems incorporate an end-device-positioning signal, which ensures the fuel and air positioners have moved to their pre-specified positions for a specific firing rate. This signal, while not actually proving final end device position and true fuel-air ratio flow, is a market improvement over FPC systems.

The new systems are gaining wide acceptance with many users who have traditionally used FPC systems and are seeking an economic means to improve overall combustion efficiency. The modern PPC system is suitable for boilers ranging from 100 through 900 boiler horsepower operating with relatively stable loads. Larger systems are also becoming more prevalent.

Modern electronic positioning PPC systems can hold excess oxygen levels to within 3-4 percent on many applications. It should be noted however, that when holding excess oxygen levels to these minimums the PPC control strategy should be used with caution in applications with extremely fast load swings. Controllers and positioners, which might be set too tight may not properly respond and still maintain a safe fuel-air ratio on large and very fast upsets. This is due in part to the lack of process variable feedback in the fuel-air system.

And like the FPC system, it is impossible for the PPC system to compensate for any changes in fuel or combustion air characteristics. Thus, issues such as fluctuations in fuel pressure, air temperature or humidity will have adverse effects on combustion processing using this system.

Series Metered Control System

The series metered control (SMC) is common on larger boilers (above 750 Bhp) where load changes are neither large nor frequent. In this application both the fuel and the air are metered. The Boiler Master regulates combustion air flow by setting the air flow setpoint. The air flow controller then cascades the air flow signal to the fuel controller as its remote setpoint. A ratio algorithm is applied to the remote setpoint signal sent to the fuel controller to adjust the fuel-air ratio. The ratio algorithm compares the remote setpoint cascaded to the fuel controller by the air flow and positions the fuel flow control valve to maintain the specified ratio between the two.

This ratio algorithm has an inherent lag in it due to the fact that the air controller is always directing the fuel controller's function; air always leads fuel. This lag provides a desirable lean furnace on demand rise, as the air controller must respond to the Boiler Master before sending a remote setpoint

Figure 3: Series Metered Fuel-Air Ratio Control

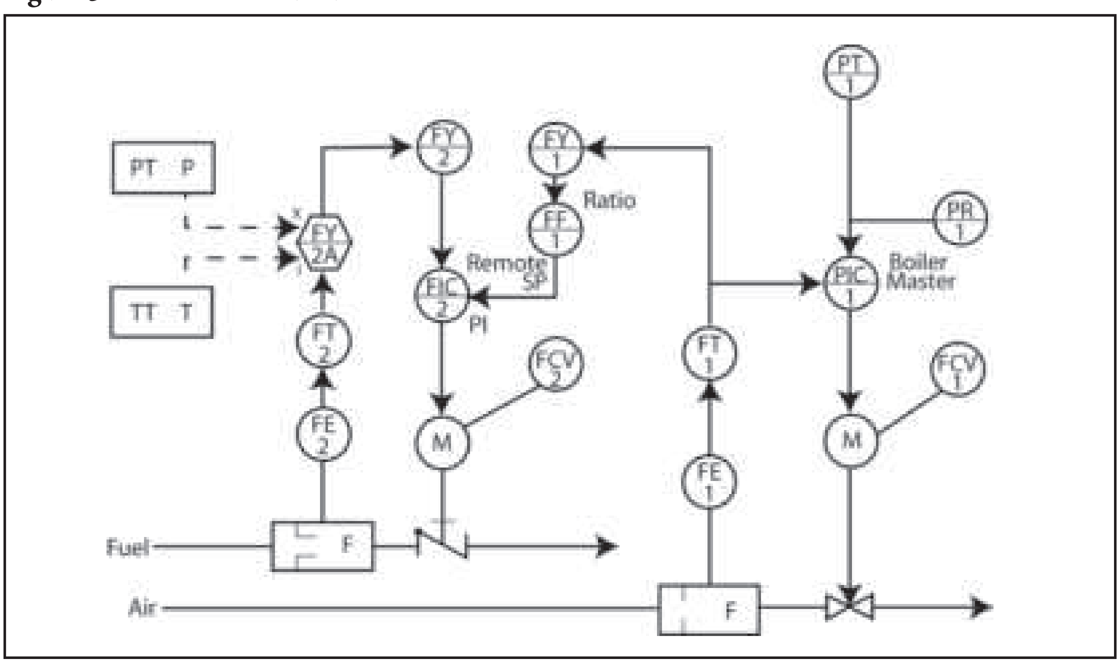
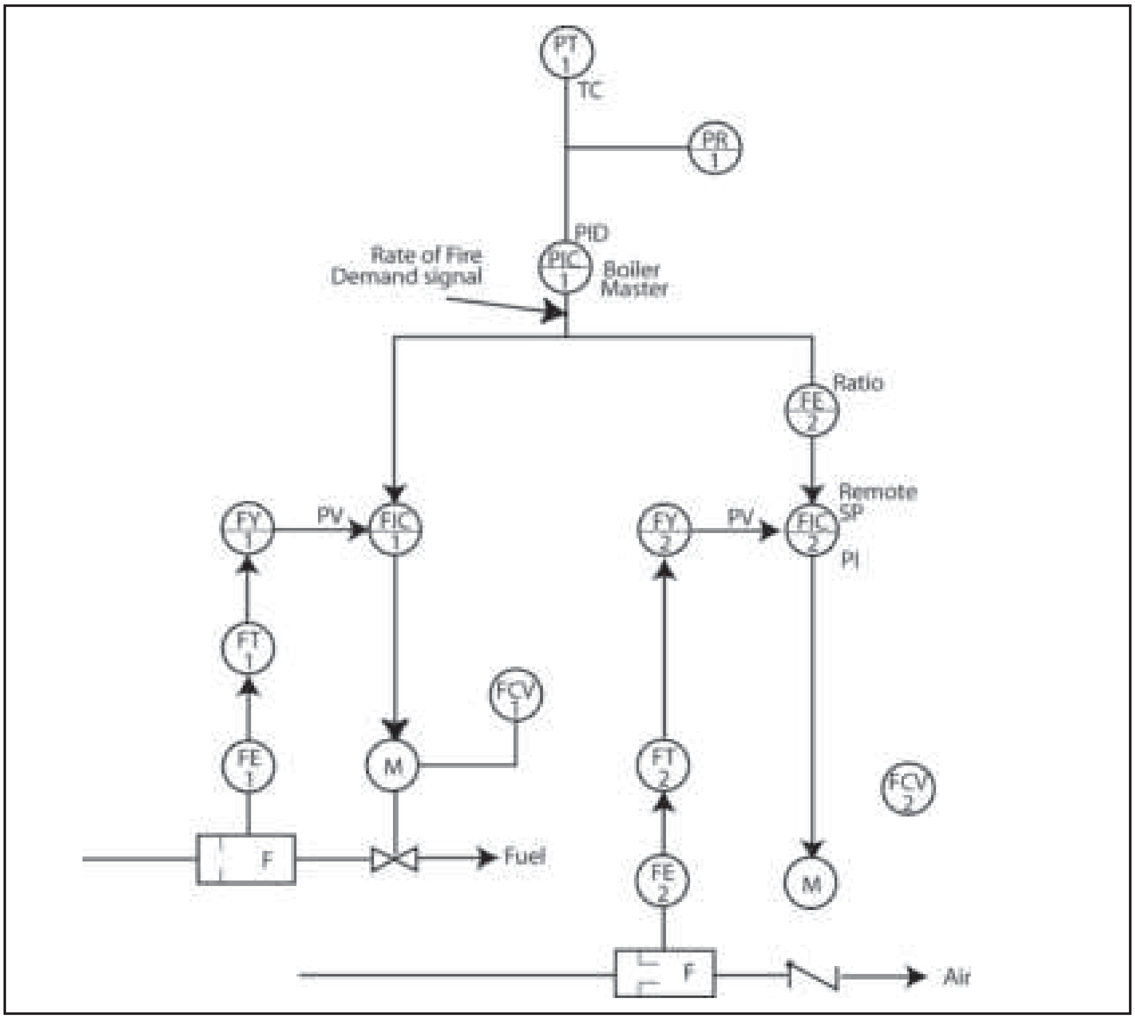


Figure 4: Metered Parallel Fuel-Air Ratio Control



to the fuel controller. However on a fast-falling demand the lag between the air controller and fuel controller can result in the air flow overshooting the fuel flow resulting in a crossover-fuel rich furnace.

Because of this lag characteristic, the series control system is only adequate for near steady state conditions due to its inability to react to fast falling load swings. To compensate for these possible overshoots and lag times, excess oxygen levels in series control systems are normally set at 5-8 percent. The use of an oxygen trim system is then incorporated to adjust the excess oxygen levels down to 3-4 percent during steady state operation.

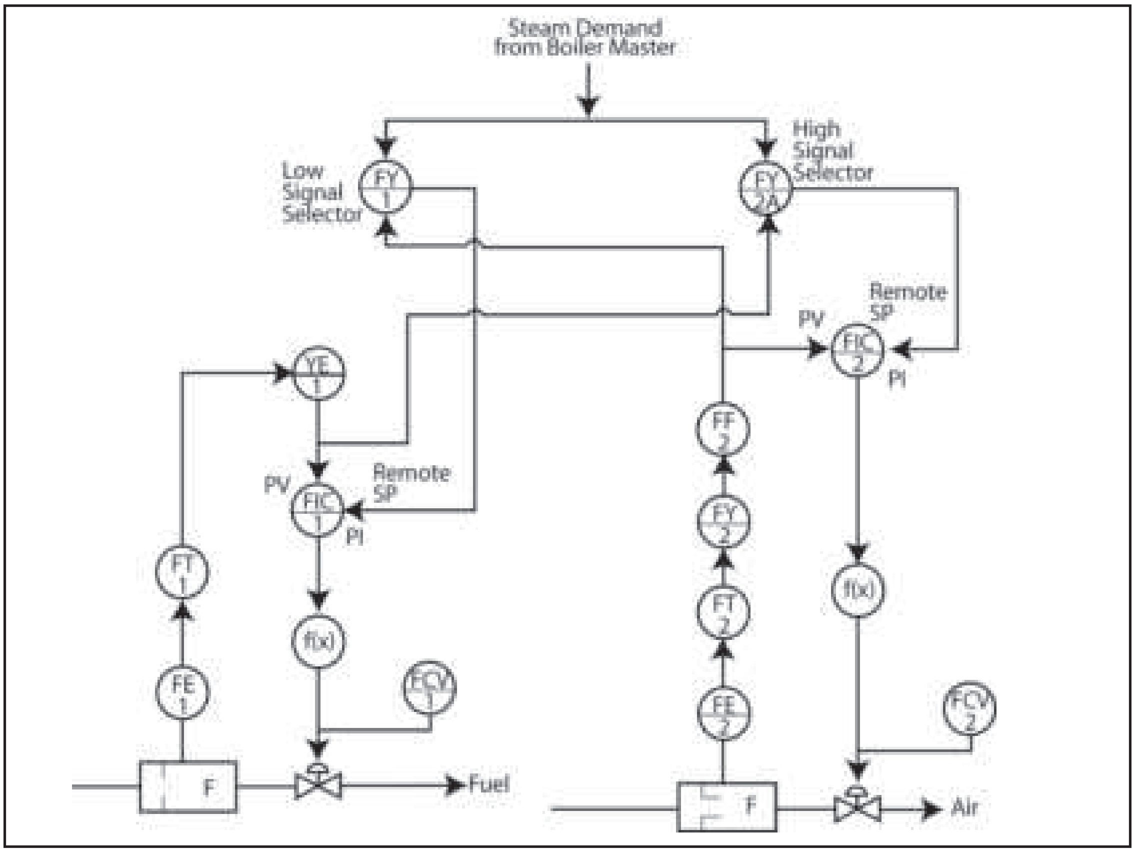
Significant improvements in the accuracy of the flowing process variables fuel and air, may be made using SMART temperature and pressure compensated transmitters, thus improving the overall accuracy of this and subsequent metered systems.

Metered Parallel Positioning Control

Boilers operating at 1,000 boiler horsepower and above commonly incorporate the metered parallel positioning control system. The metered parallel positioning control (MPPC) operates the fuel and air control loops in parallel (as opposed to series) from a single setpoint generated by the boiler master controller. The combustion air setpoint is ratioed which establishes the fuel-air proportions.

By allowing for customization of the fuel-air ratio the amount of excess oxygen in the exhaust gases may be reduced to about 3-4 percent as opposed to the 5-8 percent normally found in the series metered control strategy. In practice however, the excess air is set at about 4.5-5 percent to compensate for barometric changes in air density. The use of an oxygen trim system is then incorporated to adjust the excess oxygen levels down to 2.5-3 percent during steady state operation.

Figure 5: Cross Limiting or Lead-Lag Fuel-Air Ratio Control



The MPPC system relies on near identical response from both the air and fuel control loops to prevent fuel rich or air rich mixtutres in the furnace. The difficulty in maintaining this near identical response limits the application of the MPPC system to applications with modest demand swings.

Like the Series system, the traditional MPPC system does not have any feedback to the opposing flow controllers, i.e., fuel does not recognize air and air does not recognize fuel. This absence of feedback can result in a combustion imbalance on large or very fast load swings, resulting in either a fuel-rich or lean furnace. To compensate for the lack of feedback found in the MPPC, these systems are normally set-up with additional excess air to over compensate for fuel flow during setpoint excursions, thus maintaining an air-rich furnace on transition.

Cross-Limited Metered Control

Cross-limited metered parallel positioning control, (a.k.a. cross-limited control (CLC) or lead-lag control (LLC)), improves on the MPPC strategy by interlocking the fuel-air ratio control through high and low selectors. This interlock function prevents a fuel-rich furnace by forcing the fuel to follow air flow on a rising demand, and forcing air to follow fuel on a falling demand.

The CLC system is a dynamic system, which easily compensates for differences in response times of the fuel and air end devices. This flexibility allows its use in systems that experience sudden and large load swings, as well as very precise control at steady state operation.

The CLC operates as follows. In steady state, the steam demand signal, fuel flow and air flow signals to the high and low selectors are equal. Upon a demand increase the **low** selector applied to the fuel loop forces the fuel flow to follow the lower of either the air flow or steam demand setpoint. Conversely on a falling demand the **high** selector applied to the air controller forces the air flow to follow the higher or either the fuel flow or demand setpoint. This high/low selector function insures that the burner transitions are always air rich/fuel lean thus preventing a fuel rich furnace environment.

The cross-limited control system can easily maintain excess oxygen levels in gas burners to 3-4 percent and 2.5-3 percent in No. 2 oil systems. Additionally, since fuel flow cannot increase (cross-limited) until air flow has begun to increase, fuel cannot overshoot air flow. The use of an oxygen trim system is then incorporated to adjust the excess oxygen levels down to 2-2.5 percent during steady state operation.

Because of the CLC system's capability for close tolerance control, it is suited for all sizes of boilers, which can support the systems cost economically. Additionally the CLC system is readily adapted to oxygen trim control as well as being suited for low NO_X burner applications.

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